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ASSESSMENT OF COMPRESSIVE STRENGTH OF CONCRETE PRODUCED WITH FINE AGGREGATE FROM DIFFERENT LOCATIONS IN KADUNA STATE

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Abstract
Building Collapse from failure of structures has been a major concern for researchers today. This is traceable to several factors, one of which is the quality of the materials used during construction, as the quality of concrete is known to depend on the type of cement, water and aggregates used. Since coarse and fine aggregates occupy up to 70-75% of the concrete volume, it is necessary that the quality of aggregates be astutely ascertained. The objective of this research is to establish the best locations of fine aggregate in Kaduna state in order to facilitate its selection for construction purposes. A water-cement ratio and prescribed mix of 0.55 and 1:1.5:3 targeting a concrete of grade M20 was adopted for 100 x 100 x 100 mm cubes. This research examined the engineering properties of fine aggregate which are used in concrete works in Kaduna. Fifteen sources from the three senatorial districts in Kaduna (Kaduna North, Kaduna South and Kaduna Central) were identified from which fine aggregate samples were collected for examination. The test results revealed that the specific gravity of the samples falls between 2.34 and 2.85 and fineness modulus between 2.36 and 3.3. The compressive strength after curing for 7 days varies between 18.5 N/mm^2 and 26.4 N/mm^2, and after 28 days curing varies between 23.3 N/mm^2 and 30.1 N/mm^2, all for same prescribed mix, cement grade and coarse aggregate type. Concrete produced with fine aggregate from Kaduna South L.G shows the highest strength after 28 days while the concrete from Kajuru L.G has the lowest compressive strength after 28 days.

Keywords: *Concrete, compressive strength, specific gravity, fine aggregate.*

Introduction

Concrete is known as one of the most popular artificial construction materials on earth and the most widely used construction material in Nigeria (Klee, 2009, Odeyemi*et al.*, 2021). It is a composite material with natural aggregate as a major constituent. Traditionally, concrete is made up of cement, aggregate (coarse and fine) and water in an appropriate ratio which hardens up to form a rock-like mass (Gideon *et al*, 2015). These individual constituents have their various influences on the strength of the concrete consequently produced (Deodhar, 2009). For example, cracking is one common phenomenon due to the relatively low tensile strength as well as the presence of micro pores which could be mitigated by the presence of fines (Oriola *et al.,* 2018).

The rock-like mass substance formed by the constituent mixture hardens over time. It is cured to improve the performance properties of the concrete such as strength, durability and wear resistance. The curing is achieved by keeping the concrete saturated in order to reduce the water-filled spaces through a chemical process known as hydration. The strength, stiffness, and fracture energy of concrete for a given water/cement ratio depend on the type of aggregate used (Abdullahi, 2012). The compressive strength of concrete cannot exceed that of the aggregate contained therein (Neville and Brooks, 2010).

Aggregates can be referred to as an inert, inexpensive material spread throughout a cement paste (mixture of cement and water) in order to produce a large volume of concrete. It has a great influence on concrete performance because of its physical, thermal and chemical properties which deprive it of a true inert substance (Lennon and Moore, 2003). Aggregates occupy 70% to 75% of the volume of concrete which gives it a dominant effect on the overall performance of concrete in both fresh and hardened state (ACI, 2007). The aggregates in concrete are of two types namely fine and coarse aggregate. The aggregate with size less than or equal to 5 mm is termed fine aggregate while that with size above 5 mm is termed coarse aggregate.

In Nigeria, especially Kaduna State, river sand is the most common material used as fine aggregate in concrete production. This is because of its availability and well graded nature. River sand is mainly used for all kinds of Civil Engineering construction projects. The type of fine aggregate used in concrete production can influence the properties of the concrete. This is due to their variation in fineness, shape, and some other physical features of the fine aggregate. In construction project, Civil Engineers can specify the nature of the fine aggregate to be used but to know exactly where such aggregate should be obtained is a major problem to contractors.

Materials and Methods

The materials used for this research include:

Cement

The cement used for this study is Dangote Ordinary Portland Cement (32.5R) which conformsto NIS 444-1 (2003) requirements.

Fine Aggregate

The fine aggregates used for this study conformed to BS EN 1260:2002+A1:2008, 2008 and it passed through sieve 4.75mm. Fifteen different samples of fine aggregate were collected and all were ensured to be moisture-free before being used for the concrete production.

Coarse Aggregate

The coarse aggregate used for this study conforms to BS EN 1260:2002+A1:2008, 2008.

Water

The water used for the study is clean water obtained from bore-hole in NDA Kaduna. The batching of the fine and coarse aggregates are shown in Plates 1(a) and (b), respectively.

Plate 1(a): Batching of fine aggregate

Plate 1(b): Coarse aggregate on weighing balance

A prescribed mix – ratio containing cement, sand and coarse aggregate in proportion of 1:1.5:3 with water-cement ratio of 0.55 targeting a concrete strength of class M20 was adopted for 100 x 100 x 100 mm cubes. A total number of 180 cubes were produced for all the selected local government from the three geopolitical zones in Kaduna state. The concrete specimens were cured for 7, 14, 21, and 28 days. The density and the compressive strengths of the concrete cubes were determined at the end of the curing ages. The proportion by weight for cement, fine aggregate and coarse aggregate are 4773.6 g, 7927.2 g and 15340 g, respectively for 12 cubes allowing 10% waste. Plates 2(a) and (b) showed the mixing of concrete constituents and placing of the concrete mould, respectively

Plate 2(a): Mixing of concrete constituents

Plate 2(b): Placing the mixed concrete inside mould

Slump Test

Concrete slump was carried out from batch to batch to check the uniformity quality of the concrete. The slump was carried out in accordance to ASTM C143 (2014). Plate 3 showed sample of the slump test that was carried out.

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Plate 3: Slump test sample

Compressive Strength

The compressive strength test was conducted on the concrete cubes at the age of 7, 14, 21 and 28 days of curing, respectively for all the concrete samples from all the fifteen locations considered in the study. The test was made to conform to BS EN 12390-3 (2019). The weight of each cube was taken and recorded against the actual dimension in order to obtain the density of all the cubes. Plates 4 and 5 show the concrete cubes in curing tank and compressive strength testing.

Plate 4: Concrete cubes in curing tank

Plate 5: Testing of compressive strength

Results and Discussion

Aggregates and Cement

The preliminary test carried out on both cement and fine aggregate both include specific gravity, consistency, setting time, and particle size distribution. The test were carried out in accordance with the provision in BS 812 Part 2, BS EN 196-3 (2016), and BS EN 933-1 (2012), respectively. The results are presented in Tables 1 – 3.

Table 1: Characterization of the Used Cement

Test	Result	Code Specification	Code
Initial Setting time	75 min	≥30 Minutes	BS EN 197-1:2011
Final Setting time	482 min	≤600 Minutes	BS EN 197-1:2011
Consistency	30%	26-30%	BS EN 197-1:2011
Specific Gravity	3.11	3.15	BS EN 197-1:2011

Table 1 showed all tested properties of the cement used which all falls within specified limit.

Table 2: Specific Gravity of the Used Fine Aggregate

Sample	Result	Code Specification	Code
Chikun L.G	2.64	2.3-2.9	ACI Education Bulletin, 2007
Igabi L.G	2.43	2.3-2.9	ACI Education Bulletin, 2007
Kaduna North L.G	2.56	2.3-2.9	ACI Education Bulletin, 2007
Kaduna South L.G	2.74	2.3-2.9	ACI Education Bulletin, 2007
Kajuru L.G	2.58	2.3-2.9	ACI Education Bulletin, 2007
Lere L.G	2.52	2.3-2.9	ACI Education Bulletin, 2007
Makarfi L.G	2.71	2.3-2.9	ACI Education Bulletin, 2007
SabonGariLg	2.85	2.3-2.9	ACI Education Bulletin, 2007
Soba L.G	2.62	2.3-2.9	ACI Education Bulletin, 2007
Zaria L.G	2.70	2.3-2.9	ACI Education Bulletin, 2007
Jemala L.G	2.68	2.3-2.9	ACI Education Bulletin, 2007
Kachia L.G	2.34	2.3-2.9	ACI Education Bulletin, 2007
Kagarko L.G	2.80	2.3-2.9	ACI Education Bulletin, 2007
Kauru L.G	2.53	2.3-2.9	ACI Education Bulletin, 2007
ZangonKataf L.G	2.69	2.3-2.9	ACI Education Bulletin, 2007

The specific gravity of all the fine aggregate samples vividly shown in Figure 1 fall between 2.3 – 2.9 in accordance with a report by Kosmatka*et al*. (2003), which submits that most natural aggregate fall between 2.4 and 2.9. ASTM C33 (2003) also specifies that specific gravity should fall between 2.4 and 3.0 for normal weight aggregate. Similar results were obtained by Ajagbe*et al.* (2018) and Bala*et al.* (2015) on fine aggregate from different sources. Table 3 shows results of the fineness modulus of the aggregates.

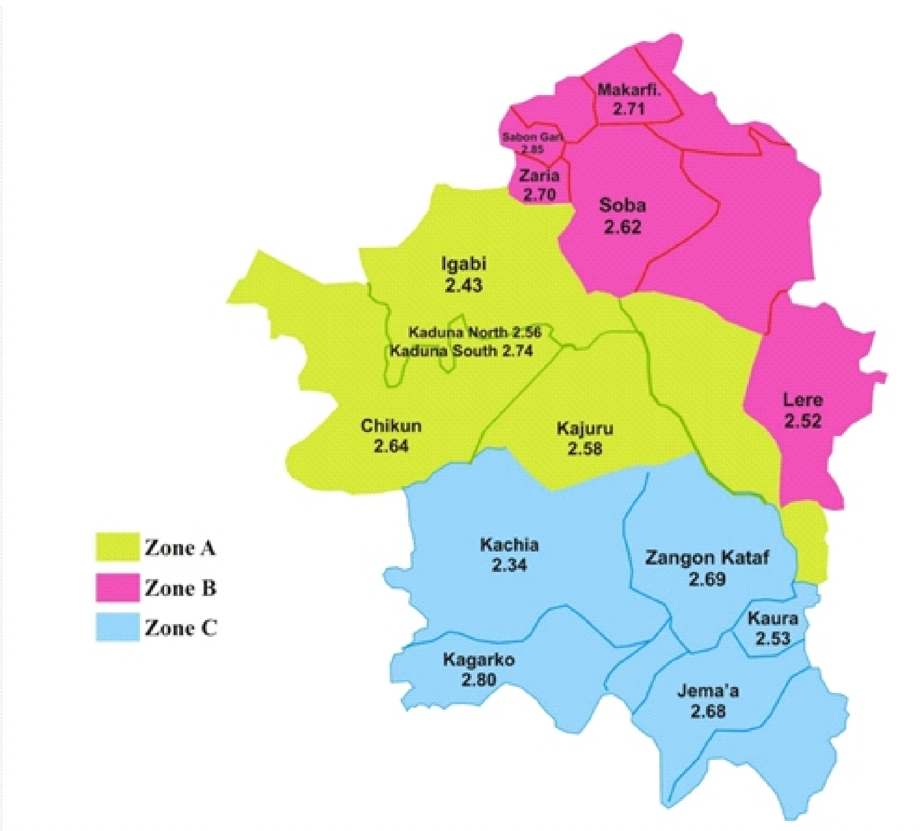

Figure 1:Specific gravity of Fine aggregates in Kaduna State Local Government Areas

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Table 3: Fineness Modulus of the Used Fine Aggregate

Sample	Result	Code Specification	Code
Chikun L.G	2.64	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Igabi L.G	2.43	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Kaduna North L.G	2.56	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Kaduna South L.G	2.74	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Kajuru L.G	2.58	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Lere L.G	2.52	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Makarfi L.G	2.71	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Sabon Gari L.G	2.85	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Soba L.G	2.62	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Zaria L.G	2.70	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Jema'a L.G	2.68	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Kachia L.G	2.34	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Kagarko L.G	2.80	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Kaura L.G	2.53	2.1 – 3.5	BS EN 12620:2002+A1:2008.
Zangon Kataf L.G	2.69	2.1 – 3.5	BS EN 12620:2002+A1:2008.

The result of the sieve analysis for the sand samples as shown in Table 3 and Figure 2 gives the fineness modulus range from 2.34 to 2.85. This indicates that all the samples are adequate for construction as a fine aggregate since is within the range of 2.1 and 3.5 recommended by BS EN 12620:2002+A1:2008. Although, the fineness of the sand samples from Kachia and Jema'a are more pronounced in their values than samples from other locations. Similar results were obtained by Bala*et al*. (2015) who worked on fine aggregate from different sources. A plot of the particle size distribution for Kaduna Central district, Kaduna North district samples, and Kaduna South district are shown in Figures 3, 4 and 5, respectively.

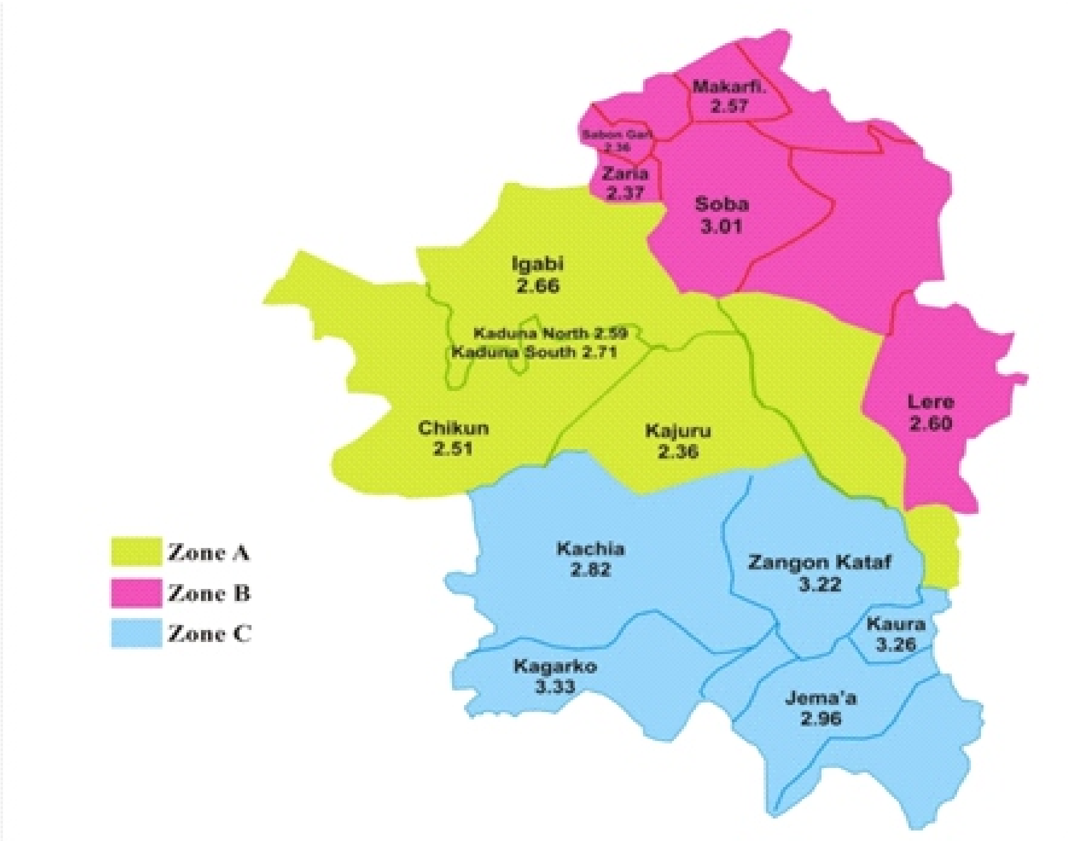

Figure 2: Fineness Modulus of Fine Aggregates in Kaduna State Local Government Areas

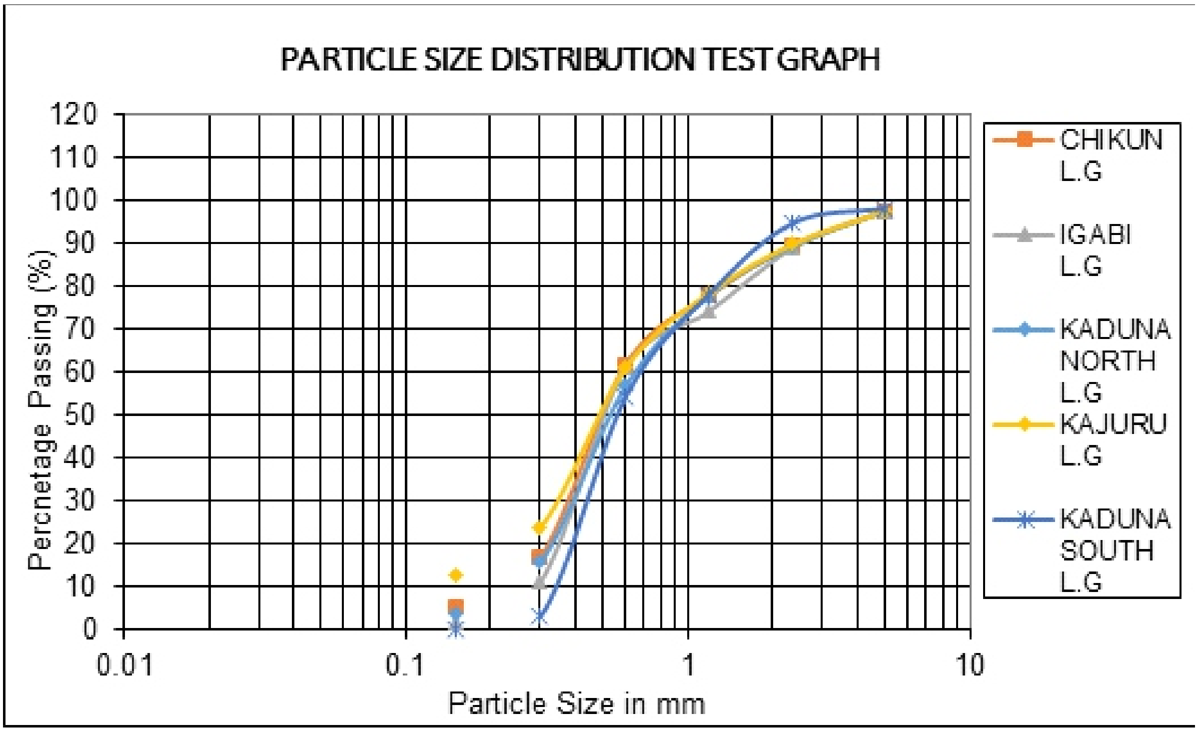

Figure 3: Particle size distribution for Kaduna Central district samples

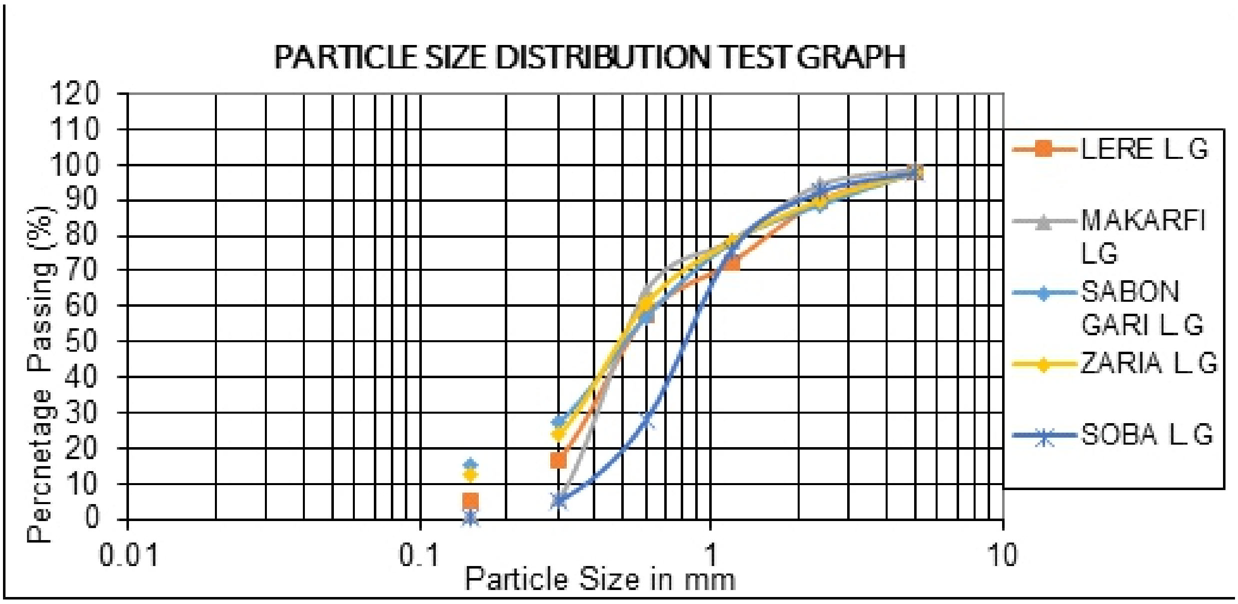

Figure 4: Particle size distribution for Kaduna North district samples

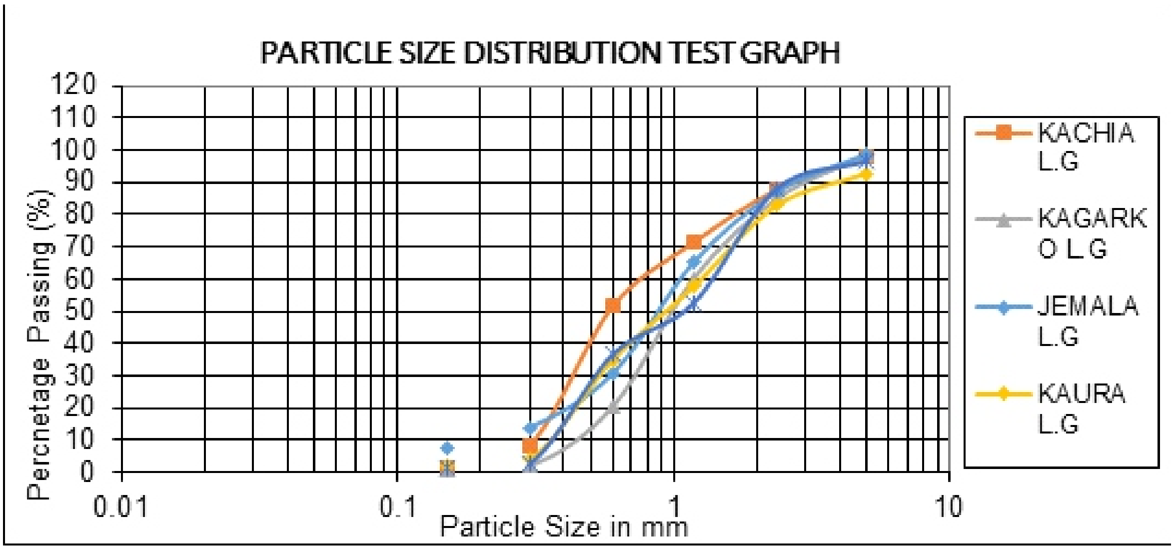

Figure 5: Particle size distribution for Kaduna South district samples

Workability of Fresh Concrete
The result of the slump test as a measure of the workability for the samples obtained from the samples gotten from the fifteen Local Government Areas are shown in the Figure 6.

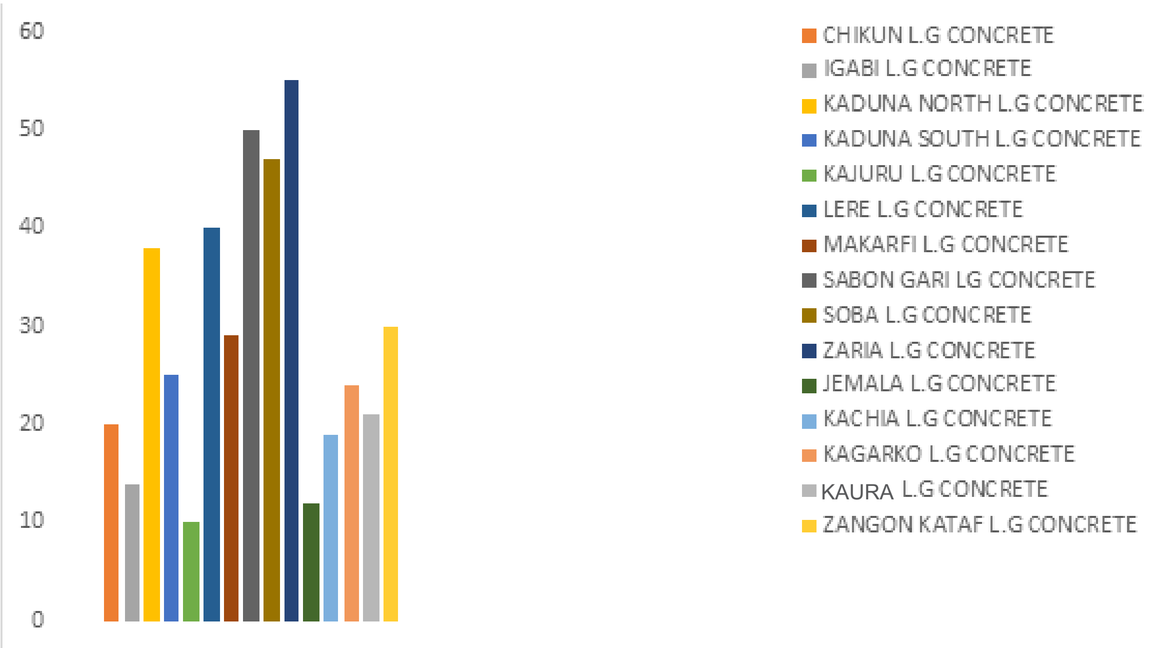

Figure 6: Slump height of concrete

The slump height varies with different fine aggregate samples. The slump for all the samples considered falls into the category of a true slump according to ASTM C143 (2014).

Compressive Strength of the Concrete
The compressive strength of concrete cubes obtained using the respective fine aggregates, same prescribed mix, cement grade and coarse aggregate type was presented in Table 4 and Figure 7.

Table 4: Compressive Strength of Concrete

Senatorial District	Sample	Mean Compressive Strength (N/mm^2)			
		7 Days	14 Days	21 Days	28 Days
	Chikun L.G	20.3	23.2	24.1	25
	Igabi L.G	24.9	27.7	28.1	28.7
	Kaduna North L.G	24.4	26.9	28.2	29.7
ZONE A	Kaduna South L.G	25.3	27.3	28.5	30.1
	Kajuru L.G	18.5	20.6	22	23.3
(KADUNA CENTRAL)					
	Lere L.G	23.6	26.7	27.9	28.6
	Makarfi L.G	24.2	26.1	27.0	28.8
ZONE B	Sabon Gari L.G	26.4	27.7	28.0	29.1
	Soba L.G	22.7	26	27.0	27.4
(KADUNA NORTH)	Zaria L.G	20.7	22.3	25.1	25.4
	Jema'a L.G	20.6	24.3	24.4	25.7
	Kachia L.G	21.8	23.8	26.8	27
ZONE C	Kagarko L.G	22.9	25.0	27.6	28.5
	Kaura L.G	19	22.3	25	26.7
(KADUNA SOUTH)	Zangon Kataf L.G	20.3	23.2	25.8	27.1

From the results shown in Table 4 and Figure 7, all the concrete cube samples met the minimum specification of compressive strength (13.5 N/mm^2) for grade 20 concrete at 7 days curing age, but the concrete cubes from Zone A have more pronounced early strength with compressive strength (25.3 N/mm^2, 24.9 N/mm^2 and 24.4 for Kaduna South, Igabi and Kaduna North Local Government respectively), except for Chikun and Kajuru with lower early strength, while Sabon Gari shows the highest early strength for all the concrete samples (26.4 N/mm^2).

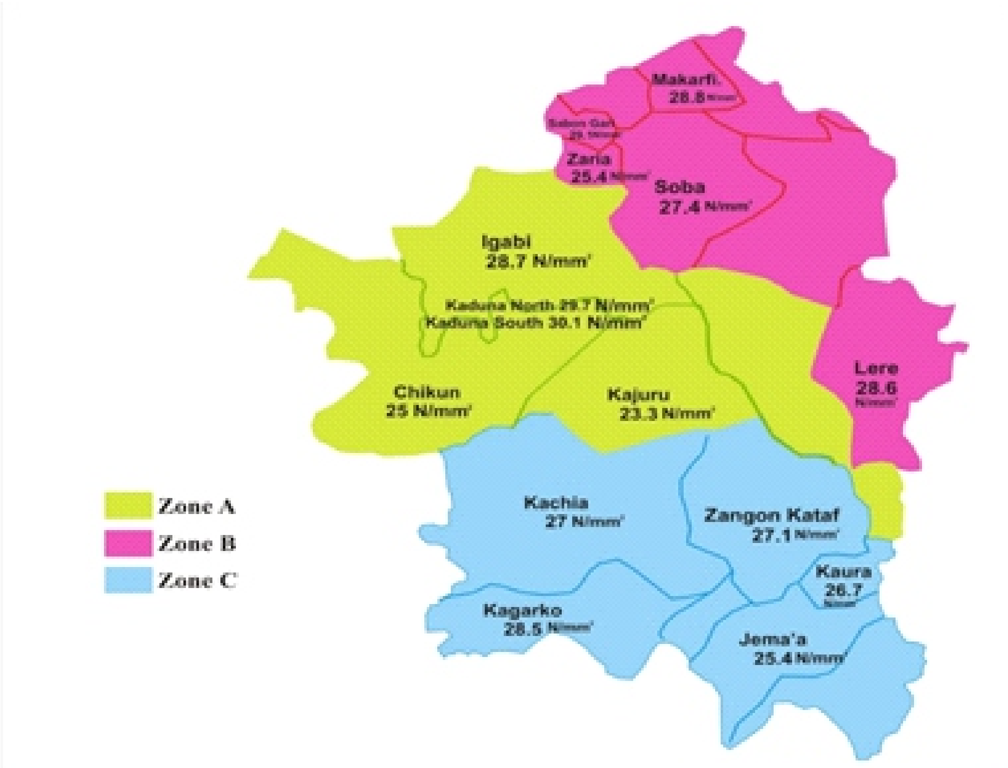

Figure 7: Compressive Strength of Concrete Cubes at 28 days of curing

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The characteristic strength (20 N/mm^2) which is the required strength for grade 20 concrete after 28 days was attained by all the concrete cube samples, while the target strength (27 N/mm^2) was not achieved by some of the concrete cubes, particularly samples from Chikun, Kajuru, Zaria, and Jema'a Local Government Area with strength of 25 N/mm^2, 23.3 N/mm^2, 25.4 N/mm^2 and 25.7 N/mm^2, respectively.

Two-way Analysis of Variance (ANOVA)

The effect of the curing age and fine aggregate samples on the concrete cubes was determined using ANOVA for different sample zones and the result is presented in Table 5, 6 and 7 for Zone A, B and C, respectively.

Table 5: Two-Factor without Replication for Zone A

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
7 Days Curing	5	117.6	23.52	4.347
14 Days Curing	5	128.8	25.76	4.198
21 Days Curing	5	135	27	1.355
28 Days Curing	5	139.3	27.86	2.308
Lere LG	4	106.8	26.7	4.886667
Makarfi LG	4	106.1	26.525	3.6625
SabonGari LG	4	111.2	27.8	1.233333
Soba LG	4	103.1	25.775	4.549167
Zaria LG	4	93.5	23.375	5.129167

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	53.3135	3	17.77117	42.07023	1.21E-06	3.490295
Columns	43.763	4	10.94075	25.90037	7.98E-06	3.259167
Error	5.069	12	0.422417			
Total	102.1455	19				

The result shows that effect of curing age and Fine aggregate samples on the compressive strength are statistically significant, ($F_{CAL} = 287.5 > F_{CRIT} = 3.26$) for curing days while ($F_{CAL} = 155.37 > F_{CRIT} = 3.49$) for Fine aggregate samples.

Table 6: Two-Factor without Replication for Zone B

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
7 Days Curing	5	113.4	22.68	9.472
14 Days Curing	5	125.7	25.14	9.673
21 Days Curing	5	130.9	26.18	8.737
28 Days Curing	5	136.8	27.36	9.208
Chikun LG	4	92.6	23.15	4.15
Igabi LG	4	109.4	27.35	2.836667
Kaduna North LG	4	109.2	27.3	5.046667
Kaduna South LG	4	111.2	27.8	4.093333
Kajuru LG	4	84.4	21.1	4.22

ANOVA

Source of Variat ion	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	59.508	3	19.836	155.3734	7.25E-10	3.490295
Columns	146.828	4	36.707	287.5222	8.41E-12	3.259167
Error	1.532	12	0.127667			
Total	207.868	19				

The result shows that effect of curing age and fine aggregate samples on the compressive strength are statistically significant, (F_{CAL} = 25.90 > F_{CRIT} = 3.26) for curing days while (F_{CAL} = 42.07 > F_{CRIT} = 3.49) for fine aggregate samples.

Table 7: Two-Factor without Replication for Zone C

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
7 Days Curing	5	104.6	20.92	2.217
14 Days Curing	5	118.6	23.72	1.067
21 Days Curing	5	129.6	25.92	1.692
28 Days Curing	5	135	27	1.01
Jemala LG	4	95	23.75	4.816667
Kachia LG	4	99.4	24.85	6.276667
Kagarko LG	4	104	26	6.473333
Kaura LG	4	93	23.25	11.31
Zangon Kataf LG	4	96.4	24.1	9.046667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	108.214	3	36.07133	77.90785	3.89E-08	3.490295
Columns	18.388	4	4.597	9.928726	0.000875	3.259167
Error	5.556	12	0.463			
Total	132.158	19				

The result shows that effect of curing age and fine aggregate samples on the compressive strength are statistically significant, (F_{CAL} = 9.93 > F_{CRIT} = 3.26) for curing days while (F_{CAL} = 77.91 > F_{CRIT} = 3.49) for fine aggregate samples.

Conclusion

The following deductions were drawn from the study that: the workability of all the concrete samples are classified as zero slump except that of Sabon Gari and Zaria which are true slump, workability of Chikun, Igabi, Kaduna South, Kajuru, Jemala, Kachia, Kagarko and Kaura are found to be "Very Low" with slump value between (0 – 25mm), while that of Kaduna North, Lere, Makarfi, Sabon Gari, Soba, and Zangon Kataf are found to be "Low" with slump value between (25–50 mm), only that of Zaria is found to be medium with slump value between (50 – 100 mm).

The concrete cubes from Zone A have more pronounced early strength with compressive strength (25.3 N/mm^2, 24.9 N/mm^2 and 24.4N/mm^2 for Kaduna South, Igabi and Kaduna North LG respectively), except for Chikun and Kajuru with lower early strength, while Sabon Gari shows the highest early strength of all the concrete samples (26.4 N/mm^2).

The characteristic strength (20 N/mm^2) which is the required strength for grade 20 concrete after 28 days was attained by all the concrete cubes samples, while the target strength (27 N/mm^2) was not attained by some of the concrete cube samples from Chikun, Kajuru, Zaria, and Jemala LG with strength of 25 N/mm^2, 23.3 N/mm^2, 25.4 N/mm^2 and 25.7 N/mm^2, respectively.

In general, "Zone A" is seen to have the best concrete-producing fine aggregate type judging by the highest compressive and target strength achieved from the tests.

Acknowledgement
With pain, we wish to recognize the tremendous scholarship of Late Dr. Jacob Oyeniyi Afolayan who initiated this research concept and we therefore dedicate the entire work to his loving memory.

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